Section 319
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INTEROFFICE TRUNKING AND SIGNALING

Contents

1. GENERAL

1.1 This section is intended to provide REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in the design and construction of REA borrowers' telephone systems. It discusses, in particular, the principles of operation of interoffice trunk circuits. For the purpose of this section, an interoffice trunk is defined as "the facility used to interconnect two central offices for talking and signaling purposes."

1.2 This issue No. 4 is being revised to update and expand information on the most commonly used trunking and signaling technologies and to eliminate outmoded material.

2. BASIC INFORMATION

2.1 The trunks described in this section are conversation channels between two central offices. They carry voice transmission and supervisory signals in both directions and switching information in

one or both directions. They are called "interoffice trunks" to distinguish them from the intraoffice trunks which originate and terminate within the same central office.

2.2 The trunk equipment in a central office consists basically of the trunk circuit and the signaling circuit. These elements may be combined into a single trunk circuit assembly, as in the case of loop dial trunks, or may consist of separate assemblies which are interconnected, as in the case of E and M type trunks. Various types of trunks will be described in this section.

2.3 The external transmission medium between two central offices may be wire, carrier, microwave or radio. This medium is terminated in each central office on a device designed to match the impedance of the central office to the impedance of the transmission medium. The impedance matching device is usually a repeating coil which must have the proper ratio of turns in its primary and secondary windings.

2.4 The trunk circuit has historically consisted of discrete components such as relays, resistors and capacitors. These electromechanical trunk circuits may be arranged for jack-in or rack mounting. In recent years electronic trunk circuits using solid-state discrete devices and integrated circuits have become popular. These are plug-in type circuits which take up considerably less space than their electromechanical counterparts. Whether electronic or electromechanical, the basic operation of the trunk circuit is the same. It connects to the external interoffice trunk medium and provides the controls for the voice, holding and signaling circuits. This includes changing the type of signals as transmitted from the subscriber's telephone to the type required for transmission over the external interoffice trunk medium.

2.5 The signaling circuit associated with each trunk receives the information originated by the hook switch and the dial at the subscriber's telephone and transmits this information to the distant end of the trunk. The information received from the hook switch indicates an on-hook (idle) or off-hook (busy) condition. The information received from the dial consists of numerical information in the form of a series of off-hook and on-hook pulses or in the case of pushbutton dialing, dual tone multifrequency pulses.

3. TYPES OF TRUNKS AND SIGNALING

3.1 The name of the type of trunk is usually derived from the method of operation employed. The term "signaling" refers to the means used to transmit trunk seizure information, receiver "on-hook" and "off-hook" information (supervision) and dialing between two offices over an interoffice trunk.

3.2 Signaling may be either DC or AC. The most commonly used types of trunks and signaling are:

Type of Trunk	Type of Signaling
1. Loop	1. Loop dial, reverse battery supervision.
	2. Loop dial, battery and ground pulsing, reverse battery supervision.
2. DX	1. Polar duplex (E-M).
3. Carrier	1. Polar duplex (E-M).
	2. Single frequency.
	3. Multifrequency.
	4. Loop dial, reverse battery supervision.
	5. PCM

4. LOOP TYPE TRUNKS USING LOOP DIAL SIGNALING

4.1 Loop signaling over interoffice trunks usually involves a pair of wires over which seizure is effected through closure of a loop, dial pulsing through interruption of the loop closure or of battery and ground and supervision by battery reversal.

4.2 Figure 1 shows the basic principles of seizure and pulsing over a loop dial trunk. The talking circuit has been omitted for purposes of simplicity and only the essentials of the circuit for seizing the trunk and dialing from office A to office B are shown. The operation described in the following paragraphs is related to direct acting central offices; however, the basic operation of the trunk is the same for common control offices.

4.21 When relay R1 is seized in office A, the trunk loop to office B is closed; relay R4 operates and seizes an incoming switch in office B.

4.22 Dialing at office A causes relay R1 to open and close with the dial pulses. This causes relay R4 in office B to follow the dial pulses and transmit these pulses through the incoming switch to the central office equipment.

4.3 The loop seizure and loop pulsing type of electromechanical trunk circuit as described in paragraph 4.2 is limited to

about 1200 ohms of loop resistance. Another method of operation known as "loop seizure, battery and ground pulsing" has been devised which extends the loop limits to about 2000 ohms and with special equipment such as pulse correction to about 3000 ohms. Electronic type trunks have pulsing and supervision limits of as much as 5000 ohms. "Battery and ground" pulsing places the batteries in the two offices in series aiding, thereby extending the dialing range. Figure 2 illustrates the basic principles of operation of a "loop seizure, battery and ground pulsing" trunk. For simplicity, the talking circuit has been omitted and the equipment arranged to show only the seizure and dialing operation on a call from office A to office B. The operation is as follows:

4.31 When relay R1 is seized in office A, battery in office A is connected to the trunk loop, closing the circuit through relay R4 and the battery at office B. The battery connections in the two offices are in series aiding. Relay R4 operates and seizes an incoming switch in office B.

4.32 Dialing at office A alternately releases and operates relay R1. Relay R4 in office B follows the dial pulses. The action of relay R4 opens and closes the circuit to the incoming switch in office B, thereby relaying the dial pulses to the central office equipment.

4.33 Supervision, the passing of "on-hook" and "off-hook" information from one office to the other, is normally accomplished by "reverse battery" as described in paragraph 4.4 for either loop or battery and ground signaling.

4.4 Reverse battery supervision, as the name implies, is supervision provided by effecting a reversal of battery potential on the trunk. Figure 3 is the same as Figure 1, except that it covers answer supervision from office B to office A in addition to seizure and pulsing.

4.41 After the seizing and pulsing relay R1 has operated and closed the trunk loop, a current flows through one winding of relay SR due to the battery voltage on the trunk at office B. Relay R1 also operates relay R2 which in turn closes a circuit through to the second winding of relay SR. The current in this second winding is equal to the current in the first winding but opposite in direction. Therefore, the effects of these currents [illegible]each other and relay SR does not operate.

[illegible]d party at office B answers, a loop to relay [illegible]his relay operates and reverses the polarity [illegible]his reverses the direction of current [illegible]SR at office A. Since the currents [illegible]lay SR are now both in the same [illegible]nd extends the answer supervision

4.43 When the called party hangs up, the circuit of relay R3 is opened at office B; the relay releases and restores battery on the trunk to its original polarity. This reverses the direction of current flow through one winding of relay SR causing it to release and pass "on-hook" supervision back to the equipment in office A.

4.44 The twin wound relay SR is sometimes replaced with a single wound relay in series with a rectifier or diode. The rectifier controls the flow of current through the relay depending on the polarity of battery on the trunk.

4.5 Loop dial trunks have certain restrictions on their use:

4.51 The loop resistance limit is reached with shorter distances on physical circuits, especially where smaller gauge cables are used.

4.52 The trunk circuits are not as versatile as the E and M since they normally cannot be used with carrier.

4.6 Loop dialing finds its principal application in physical trunk groups where distances between offices are relatively short. In this case, some economies may result from the use of loop dial trunks. Loop signaling options are also available in some carrier circuits. The so-called loop dial carriers most often used in recent years are actually carriers which have self-contained trunk and signaling units so that the carrier looks like loop dial trunks to the central office equipment.

5. POLAR-DUPLEX (E-M) SIGNALING OVER DX TYPE TRUNKS

5.1 DX type signaling will provide the most reliable service, especially over long trunk loops up to 5000 ohms and where large and varying differences in earth potentials are encountered. The talking circuit also has a much better balance against AC induction. The signaling circuit uses the same cable pair as the talking circuit and no filters are required to separate the signaling frequencies from the voice frequencies.

5.2 Figure 4 shows a DX type trunk using polar-duplex (E-M) signaling. The DX relay has four windings. One line conductor is used as the signaling path and the other as the path for earth potential compensation. The operation of the DX relay is as follows:

5.21 In the idle condition, ground is applied to the M lead in both offices. The DX relays are electrically biased to the non-operated position by the P2 and P3 windings from the negative potential of the voltage divider. There is no current flowing over the trunk conductors in the idle condition unless a difference in earth potential exists between office A and office B.

5.22 If the trunk is seized from office A, battery is placed on the M lead causing the DX relay in office B to operate. At office A, current in the P2 and P3 windings is reversed tending to operate the DX relay, but the signal current through the P1 winding more than offsets this effect and the relay remains nonoperated.

5.23 When office B answers, both M leads are connected to battery and each DX relay holds operated to ground from the voltage divider. With battery on each M lead there will be no current flowing in the trunk conductors, providing no earth potential difference exists.

5.24 When earth potential differences do exist, they will produce opposite and approximately equal effects in the P1 and P4 windings at each end. The net effect on the DX relay is therefore approximately zero.

5.3 In summary, the features of DX signaling, including advantages, are as follow:

1. Very low impulse distortion.

2. Simultaneous signaling in both directions (duplex operation).

3. Earth potential compensation.

4. A single DX signaling section is limited to a maximum loop resistance of 5000 ohms. However, this range can be doubled by using two sections in tandem.

5. Can be operated satisfactorily through negative impedance type voice frequency repeaters.

6. Can be used for E and M lead extension without additional signaling pairs in conjunction with carrier terminals mounted at locations external to one or both central offices. See paragraph 5.4 for further details.

7. One possible disadvantage of DX signaling is that dial impluses can be heard across the tip and ring. This disadvantage is usually of no consequence, but one example of where a problem might be encountered is a DDD trunk from a tributary where ANI is used in the tributary. In some ticketing systems the calling number is sent to the CAMA center during conversation. The use of DX signaling on such a trunk would mean that the telephone users would hear the pulsing of the sender.

8. Electronic card type DX signaling sets are now available. Some of these electronic sets use solid-state switching networks rather than polar relays. The basic operation of the circuit is still the same.

5.4 Signal lead extension (EMX) equipment is similar to DX signaling equipment. In fact, one end of the circuit can be DX equipment. The other end, called the "intermediate end," has a two-relay signaling circuit which is designed to work into another signaling unit rather than a trunk circuit. A block diagram of this arrangement is shown in Figure 5A. Often the other signaling unit is part of a carrier terminal, although it could be any kind of E and M signaling unit. Also, both ends of the physical circuit could be EMX units. A block diagram of this is shown in Figure 5B. An example of this would be a trunk group consisting of microwave, cable pairs and finally carrier along the trunk route. Signal lead extension circuits are usually on a two-wire basis (transmission-wise), but it is also possible to use special equipment designed for four-wire operation.

5.5 They typical arrangement for connection between a trunk and an E and M signaling circuit (such as carrier or DX) is through E and M leads. The signaling circuit places ground on the E lead toward the trunk circuit during the off-hook condition. A few circuits use a third lead called the "F" lead. Instead of placing ground on the E lead, the signaling circuit connects the E and F leads together during the off-hcok condition.

5.6 As described earlier, the trunk circuit changes the M lead from ground to negative battery during the off-hook condition. In most E and M trunk circuits, the M lead has a permanent resistance ground on it. When an E and M trunk circuit is connected to a carrier signaling circuit which employs a relay on the M lead, it is usually necessary to remove the ground on the break contact and also the resistance ground in the trunk circuit. It is also customary to add a resistance-capacitance network for spark protection across the pulsing contact in the trunk circuit. Modern carrier signaling systems such as E and F type signaling utilize electronic signaling means on the M lead ("Diode Keying"). This type of carrier requires M lead signaling identical to that of a DX set. As the wrong wiring options may result in severe impulse distortions, it is highly important that the proper signaling option is installed.

5.7 An idle circuit termination or its equivalent is usually maintained acorss the trunk during an unanswered condition to prevent singing or other undesirable interference from carrier or other electronic equipment. This termination consists of a resistor and capacitor in series designed to match the impedance of the trunk to the central office. When a call is answered, the

idle circuit termination is automatically removed. An exception is a call to a point for which no charge is made; for example, a call to directory assistance. In this case no answer supervision is returned and the idle circuit termination is retained across the trunk. This causes a slight, but not serious, degradation in the level of transmission.

6. SINGLE FREQUENCY SIGNALING (SF)

6.1 Single frequency signaling systems pass the necessary signals for trunks over voice frequency facilities without interfering with normal speech patterns. SF systems transmit and receive DC signals to and from the trunk equipment in the form of loop or E and M signals. These DC signals are changed to AC on the line side and vice versa. An example of SF signaling is shown in Figure 6.

6.2 The frequency used for single frequency signaling is 2600 Hz in both directions. SF signaling may be used over any voice grade facility of any length provided it is 4-wire from end to end.

6.3 The characteristics of SF signaling systems differ considerably from those of DC signaling systems. The major differences are as follow:

6.31 Signaling time has a longer delay in SF systems.

6.32 Signaling speed and percent break range are smaller in SF systems.

6.33 The voice path is interrupted at various times in SF signaling systems.

6.34 Continuous tones can cause the SF signaling system to malfunction.

6.4 Single frequency signaling is useful in the following applications:

6.41 When a trunk group is made up of two or more different facilities, the signaling need not be repeated at the intermediate point because it passes through the entire facility from end to end.

6.42 When trunks use hybrid-type voice frequency repeaters, it is necessary to install DC signaling bypass equipment at the repeater locations, since the DC signals will not pass through the hybrid-type repeater. By using single frequency signaling the tone signals will be within the voice band and the voice frequency repeaters will amplify and pass these signals in the same manner as the voice currents.

6.5 E-type signaling is a family of transistorized single-frequency signaling units. This family has been used successfully over the years but is now being replaced by F-type signaling units.

6.6 The basic principles of operation of F-type signaling units are the same as those of E-type units. The major differences are in the packaging and the sophistication of the electronic design. The signaling, transmission and stability characteristics of F-type signaling circuits are similar, but superior, to those of E-type signaling circuits.

7. PULSE CODE MODULATION SIGNALING (PCM)

7.1 In pulse code modulation (PCM) systems, signaling information is normally transmitted in the bit stream itself. In the latest equipment the least significant bit for every channel in every sixth frame is used for signaling.

7.2 The bits in the odd-numbered sixth frames are called "A" bits, and the bits in the even-numbered sixth frames are called "B" bits. These bits are used to transmit various signaling information such as on-hook/off-hook, ringing and dial pulsing. Two-way signaling can be implemented by using the "A" bits for one direction and the "B" bits for the other.

7.3 External to the carrier system, conventional signaling methods such as E & M and loop dial can be used. Both ends of the trunk do not have to use the same signaling method.

8. MULTIFREQUENCY PULSING (MF)

8.1 Multifrequency pulsing also has the advantage of passing through the entire facility, through hybrid repeaters, changes in types of facilities, etc. It is very fast in operation, but its use is limited to those cases where the terminating office is equipped with common control equipment and arranged to receive MF signaling. Each digit is represented by a single pulse pulse consists of a combination of two, and only two, of f frequencies. These frequencies are 700, 900, 1100, 1300, a Hz. These frequencies are used in two out of five combina transmit the numerals 1 through 0. An additional frequenc Hz, is used in combination with the five previously mentio frequencies in a two out of six format to provide CAMA for functions (KP, ST, etc.).

8.2 Multifrequency signaling systems are used to transmi information only. An additional signaling unit such SF, or loop is required for supervision.

8.3 MF pulsing has advantages of speed, accuracy and ran other types of pulsing arrangements. Pushbutton dia faster than rotary dials and MF senders operate more rapid

dial pulse senders. MF signaling requires less holding time per call; therefore, a smaller number of MF senders or registers are needed.

9. START-AND-STOP PULSING SIGNALS

9.1 Pulsing between offices with registers and senders must not begin until the terminating office is prepared to receive the pulses. Pulsing with dial pulses or MF signals into senderized systems requires setup time for the incoming register. Wink and delay dial signals were developed to assure that pulsing does not begin until the incoming register is ready to receive pulses. When these methods are used, incoming registers can be provided at a lower grade of service.

9.2 The general procedure used to indicate readiness for pulsing is as follows:

9.21 In the idle condition, the trunk appears on-hook from both ends.

9.22 Off-hook is sent from the originating end as a connect signal and off-hook is returned as a recognition of seizure.

9.23 The terminating office returns an on-hook signal when it is ready to receive pulses.

9.3 Wink-start senders recognize the change from off-hook to on-hook as the start pulsing signal. Delay-dial senders recognize the on-hook as the start signal. Delay-dial senders do not test for on-hook until the original on-hook has had time to change to off-hook at the terminating office.

9.4 Wink start operation is normally used on one-way trunks and delay dial on two-way trunks. However, there are cases where the opposite is true.

9.5 When multifrequency pulsing is used, delay dial or wink start signals are always required.

10. COMMON CHANNEL INTEROFFICE SIGNALING (CCIS)

10.1 Common channel interoffice signaling can be used to pass information between processor-controlled central offices over a network of signaling links. All signaling data is transmitted via these signaling links rather than over the voice path. No SF or MF equipment is required when CCIS is used.

10.2 The major advantages of CCIS are as follow:

10.21 Because of the signaling speed of CCIS systems, calls can be set up and taken down faster. The efficiency of the trunk facilities is enhanced because of the reduced holding time of the trunks and switching equipment.

10.22 CCIS systems can carry more information than conventional signaling systems.

10.23 Signals can be sent simultaneously in both directions and can take place during conversation time without speech path interference.

10.24 CCIS is more reliable and flexible than conventional inband signaling systems.

10.25 CCIS is more resistent to fraudulent signaling.

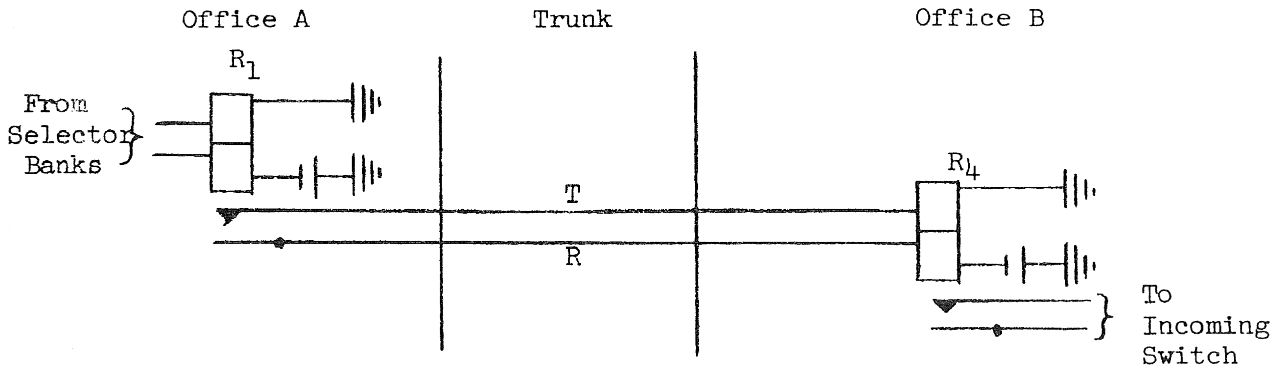

FIGURE 1

BASIC LOOP SIGNALING

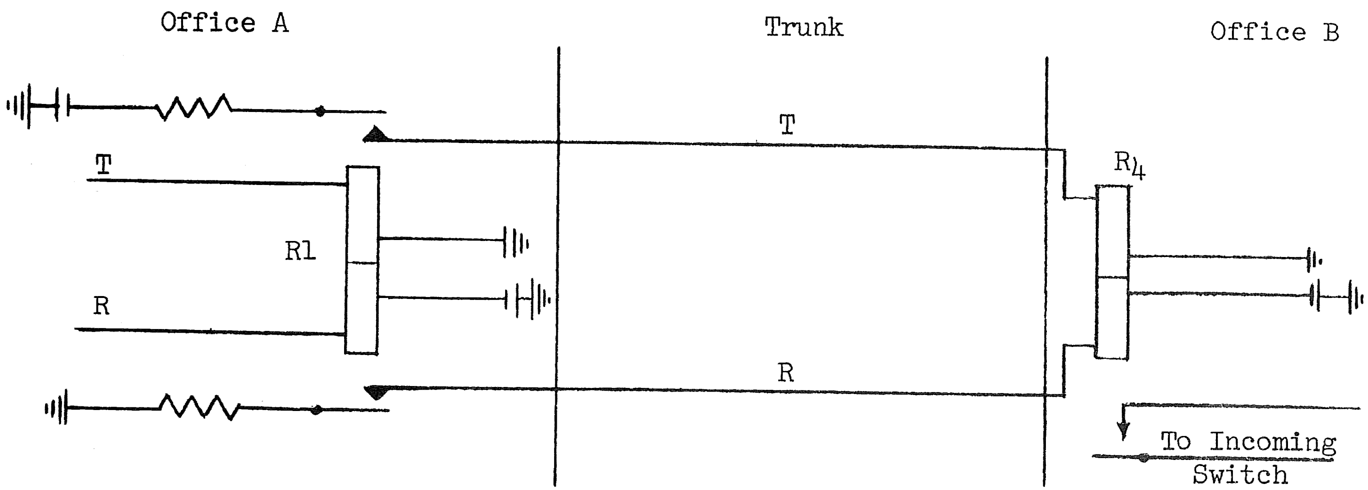

FIGURE 2

TTERY AND GROUND PULSING LOOP SIGNALING

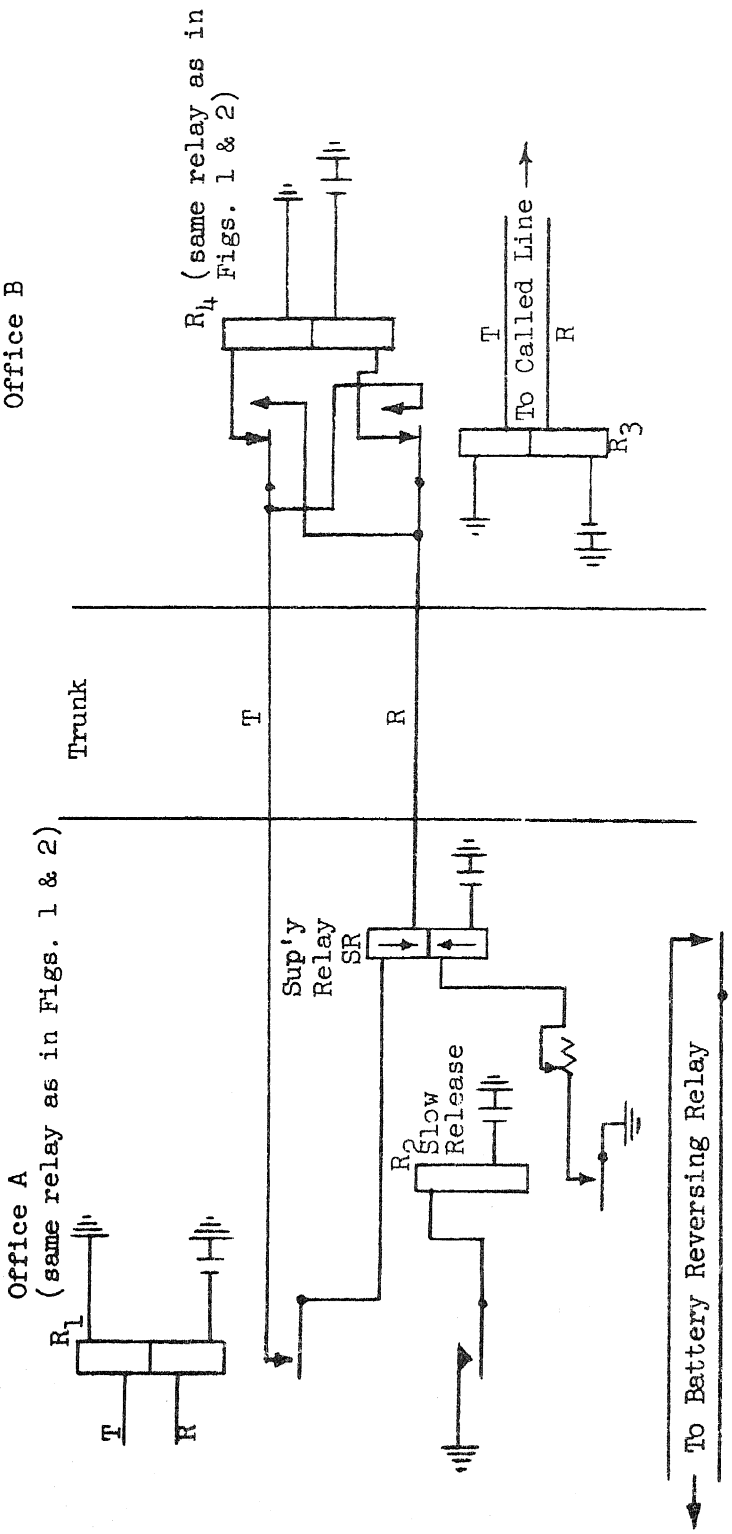

FIGURE 3

LOOP SIGNALING REVERSE BATTERY SUPERVISION

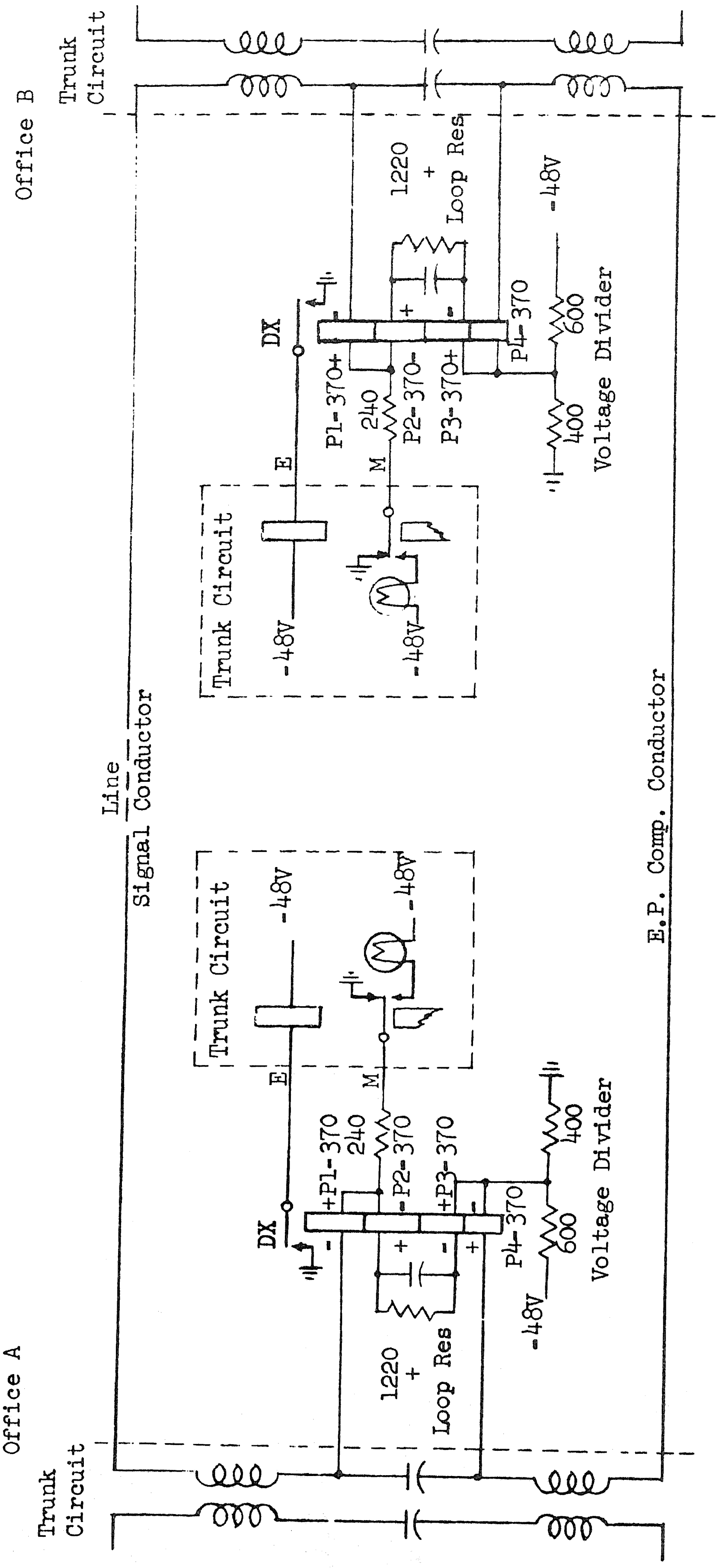

FIGURE 4

E-M SIGNALING USING DX FACILITIES

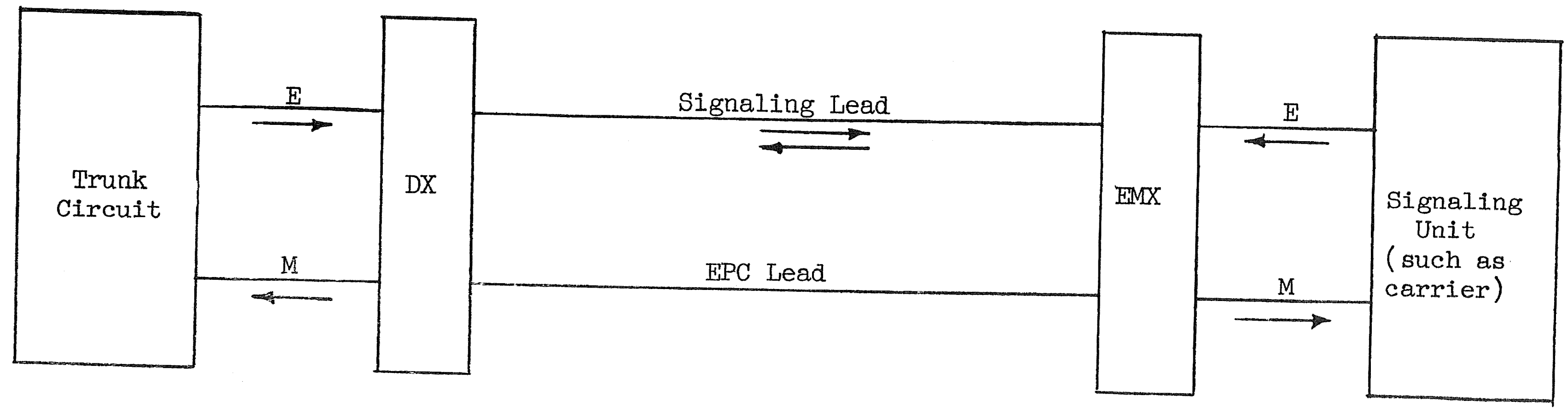

FIGURE 5A

SIGNAL LEAD EXTENSION FROM TRUNK CIRCUIT TO SIGNALING UNIT

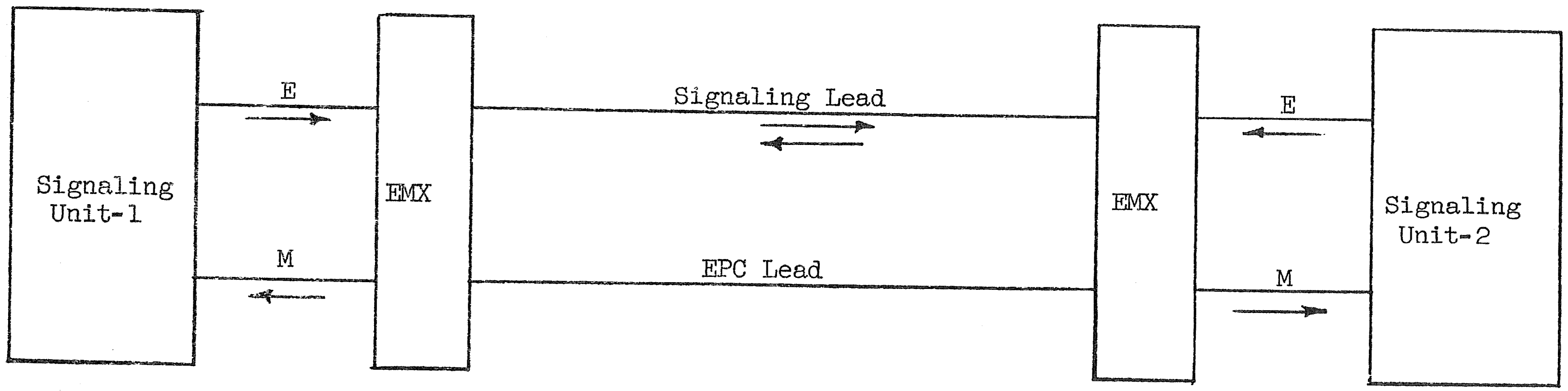

FIGURE 5B

SIGNAL LEAD EXTENSION BETWEEN SIGNALING UNITS

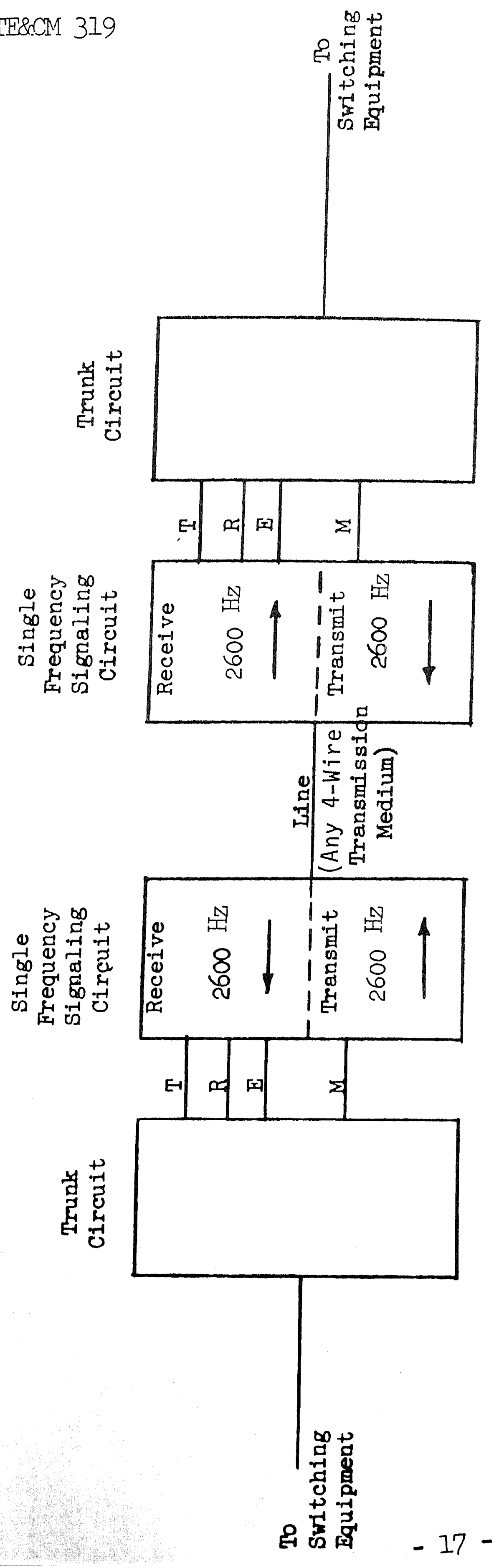

FIGURE 6
SINGLE FREQUENCY SIGNALING